Electro-horticulture

Electricity on the Farm and in the Garden

J.

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with the compliments of
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ELECTRO-HORTICULTURE

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PREFACE

ELECTRICITY is analogous to heat and light, and, like them, has an influence upon the growth of plants. What this is, it is the purpose of the author to inquire into with his readers by presenting to them a summary of what has been accomplished in the comparatively new science of electro-horticulture, and by discussing with them the rationale of the action of electricity upon vegetation.

That he may afford assistance to some who are already at work, and possibly influence others to investigate into this fascinating subject, is his sole motive in offering to the public this monograph.

He has had in view the popular rather than the scientific aspect of the subject, and hence has limited himself to what he felt would most appeal to the average reader.

G. S. H.

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ELECTRO-HORTICULTURE

CHAPTER I

THE DAWN OF ELECTRO-HORTICULTURE. THE APPLICATION OF ELECTRICITY TO THE STALKS OF PLANTS

THE use of electricity in horticulture, while seemingly of recent years, had its small beginning long before the invention of the dynamo, and even antedated several years Franklin's important discovery, in 1752, by which he startled the scientific world with the announcement that he had drawn the "electric fluid" from the clouds by means of a kite, and had proved it to be identical with the electricity of the Leyden jar. As early as 1746, the very year which saw the invention of the famous Leyden jar, Von Maimbray, of Edinburgh, began to study the effects of electricity upon plant life, his first experiment being with two young myrtle trees. He simply passed the current down through them to the soil, and found that it stimulated their growth. Soon experimenters upon the continent were at work along the same line, and their results were such that they readily agreed with him that electricity exerted a favorable influence upon vegetation. They, like Von Maimbray, passed the electricity, developed mainly by friction, through the stalks of plants to the soil. The machines they used to develop the current were so crude, and their experiments conducted upon such a small scale, that but little advance was made upon the initial experiments, and the interest accordingly waned.

In 1783, Abbot Bertholon became interested in the subject, and his investigations soon convinced him that electricity was decidedly useful in the maturing of plants. His enthusiasm reached a high pitch, and he gave vent to it in a book, *Concerning Electricity in Plants.* He devoted the larger part of it to reporting the results of his experiments, and the remainder to the description of the appliances used in furnishing electricity to the plants.

We shall briefly describe two of these devices. One consisted of an insulated rod, supported vertically, holding up some points in the air and terminating in other points directly over the plant; his intention being to draw down some of the electricity in the atmosphere and pass it through the plant into the ground. The other was more ingenious and complicated, and furnished electricity on a much larger scale. A barrel of water was placed on a cart; beside it stood the operator on an insulated stool. His body was connected by means of an insulated wire with the positive pole of a frictional-electric machine in action. As he dipped water out of the barrel by means of a large sprinkling-can it became charged with electricity from the machine. By sprinkling it upon the plants while the cart was being driven among them, the current was delivered to them by the water, and passed through them to the soil.

These currents of high electromotive force (pressure), generated by the frictional-electric machines used by Bertholon, could readily pass through the water [1] to the plants, and through them to the ground.

While Bertholon was observing the effects of devices which gave a much larger supply of electricity to plants than they could get from the atmosphere, Gardini, of Turin, was pursuing an opposite course by watching the results of experiments which entirely removed plants from the influence of atmo-

[1] That water will conduct electricity many persons have learned to their surprise when they have attempted to remove a coin from a bowl of this fluid which has been connected with one of the poles of an induction coil, their bodies having been connected with the other pole. Firemen have also learned that it is not safe to throw a stream of water over live electric wires, because the insulation may have been burned off, or removed in other ways, and a dangerous and perhaps fatal current may escape down the stream of water to their bodies. That fertile genius, Mr. Edison, not long ago startled us by suggesting that we utilize the conducting power of water in modern warfare. He spoke of rendering a fort impregnable by means of such simple machinery as a powerful force-pump to propel streams of water, and a dynamo to furnish deadly currents of electricity to them. But a handful of men would be required to run this machinery and direct the electrified streams of water upon the advancing columns of

spheric electricity. The former claimed that by increasing the supply of electricity he could markedly hasten the maturing of plants, and the latter that by depriving plants of it, he could very materially retard their growth. Gardini's method was to protect plants from the influence of the atmospheric electricity by covering them with cages of wire gauze, and then to compare them with others exposed to the action of the electricity in the atmosphere. The wire gauze which surrounded the plants conducted the atmospheric electricity away from them to the ground, and the result was that the plants drooped; when he removed the wire cages they revived again. He gave his conclusions as follows:

"1. Atmospheric electricity exerts considerable influence upon the production of vegetable matter. All things equal, plants will develop better every-

the enemy, mowing them down instantly. If it pleased these dispensers of death within the fort, they could, by reducing the strength of the current, merely temporarily paralyze their foemen, and then go out and capture them; or, if they were diabolical enough to crave some sport at the expense of their helpless victims, they, by still further reducing the strength of the current, could cause them to throw away their weapons and engage in a dance, which, while amusing to the merciless men within the fort, would be anything but pleasurable to the writhing humanity at the other end of the streams of electrified water. Of course, the enemy might come clad in rubber suits, or otherwise insulated; and then it would be a question of strength of current on the one hand, and perfection of insulation on the other. It is hardly likely that we shall have a practical test of this matter; it belongs more to the realms of electric fancy.

where where they are exposed to the action of atmospheric electricity.

"2. Plants protected from the action of the atmospheric electricity have, in the same space of time, given from fifty to seventy per cent. of fruit and seed less than the plants placed in ordinary conditions,—that is to say, to which electricity has free access.

"3. The proportion of albuminous substances does not appear to depend sensibly upon the influence of electricity, while plants that are protected from it appear to contain less water and more mineral substances.

"4. Tall plants have a harmful influence upon the development of plants that grow at their base, not only by depriving them of light and heat, but also because they absorb atmospheric electricity at their expense."

Leclerc, who was experimenting at the same time, agreed with Gardini. Celi tested the matter in another way. He planted three grains of corn in a flower-pot, and placed it under a bell-glass. In another pot of the same size, filled with the same quality of earth, he planted three similar grains, and placed the pot under a bell-glass of the same size as the former one. He provided so that each would receive the same amount of water and air. Thus both were protected from the influence of atmospheric electricity. He then arranged one of the bell-glasses so that a wire passed through its top and ended in a number of radiating points just within. This wire was connected with an insulated metallic vessel near the bell-glass, from which vessel issued a fine stream of water. The flow of water electrified the vessel, and the current passed down the wire and was dispersed within the bell-glass. Thus one flower-pot, with its imbedded corn, received a constant supply of electricity, while the other received none. It was soon noticed that the plants in the electrified air were growing faster than the others. In ten days, the former were ten centimetres high, while the latter were but eight.

These experiments were largely repeated and abundantly confirmed, yet there were experimenters who reported contradictory results. Among them was Ingenhouss, a high authority in vegetable physiology in his time (1787). His denial that electricity exerted a beneficial influence upon vegetation very much chilled the enthusiasm of those who were experimenting; but still the experiments were not discontinued.

Especially interested and active became Mr. Selim Lemstrom, of University of Helsingfors, who had noticed that in Lapland and in Spitzbergen plants grew with wonderful rapidity during the short polar summer, and their flowers were more brightly colored, and, if they were cereals, yielded surprisingly large crops. He attributed this to the fact that atmospheric electricity was more abundant in the polar regions than elsewhere; he knew that these regions are the peculiar homes of the aurora borealis, a generally conceded electric phenomenon. Lemstrom planted seeds in pots, and put some of them under a system of wires with points projecting downward so as to deliver the electricity from the positive pole of a Holtz machine upon the growing plants; the others were not exposed to the current. He found in six weeks (the machine being in operation five hours each day) that the plants electrically treated were forty per cent. in advance of the others. He also found that it did not matter whether the electricity was passed down through the plant or in the opposite direction.

In 1885, experiments were conducted on a larger scale in the open fields in the domain of Niemis. A system of insulated wires was erected over part of a field of barley; at short intervals were metallic points which could deliver the electricity down upon the grain. This system was connected with the positive pole of a four-disk Holtz machine, the negative pole being connected with a zinc plate buried in the earth. The machine was run eight hours a day. The result was that the crop was increased one third in the electrified part of the field. Larger claims were made in the following year by the experimenters at Brodtorp, who used the current from four electric machines.

From the many experiments conducted by Lemstrom, he concluded that electricity favorably affected the growth of wheat, rye, barley, oats, beets, parsnips, potatoes, radishes, celery, leeks, kidney-beans, raspberries, and strawberries; while carrots, rutabagas, turnips, cabbages, and tobacco were more or less injured by the electric treatment.

That the results obtained by the different investigators were not always harmonious is not strange when we consider that the experiments were performed at various points on the earth's surface, and that the time of day during which the current was applied and the length of the application were subject to wide variations.

CHAPTER II

ELECTRICITY FROM THE ATMOSPHERE APPLIED TO THE ROOTS OF PLANTS AND TO THE SOIL SURROUNDING THEM

IN 1891, Paulin, of the Agricultural School at Beauvais, France, began a series of experiments near Montbrison, with the expectation of drawing down the atmospheric electricity in more abundant quantities than had been done by previous experimenters. He erected what he called a geomagnetifer. It was merely a tall, resinous pole planted in the earth, and carrying to its top a galvanized iron rod, insulated from it by porcelain knobs, and terminating in five pointed branches. The electricity thus collected from the atmosphere was carried to the soil and distributed by means of a system of underground wires to the area of ground to be electrically influenced. His first experiment was with potatoes. The part of the field under electric influence responded in a surprising manner, as is evidenced by the following extract from a newspaper report at the time: "The eye is arrested by a perceptible irregularity in the vegetation of the field. Within a circle limited exactly by the place occupied in the earth by the conducting wires of atmospheric electricity, the potato plants possess a vigor double that of the plants occupying the rest of the earth, and that, too, without a gap, without a feeble point in this group of superb stalks, sharply circumscribed as by a line drawn by a compass."

According to the report of the committee delegated by the Montbrison Society of Agriculture to report on Paulin's experiments, a geomagnetifer twenty-eight feet high, made its influence felt over a radius of sixty-five feet, and the yield of potatoes within this electrified area was from fifty per cent. to seventy-five per cent. greater than without it. This committee was quite enthusiastic over the results of Paulin's experiments, and awarded him a special medal. He next experimented with his geomagnetifer in a vineyard, and found that grapes were much advanced in their growth, and that they were sweeter (yielding about five per cent. more sugar) and less acid. In further experiments he found that spinach and celery were markedly influenced, some leaves of the former reaching the length of one and one fourth feet, and some stalks of the latter three feet. Radishes and turnips were much improved in size and quality, and sugar-beets yielded a larger percentage of their saccharine compound. It was also noticed that potatoes and sugar-beets, electrically cultivated, were singularly free from disease, while those outside of the influence were often seriously affected.

Spechnew modified Paulin's experiment by sticking a number of poles into a field, each pole having a point at its apex, and all being connected with a system of underground conducting wires, so as to distribute the electricity to the soil. "By these means," he says, "the electricity of the atmosphere is rendered denser over the field, and the plants develop in a field of high electric tension." After five years of experimentation he was most favorably impressed with the results. He tells us that 475 pounds of rye by the ordinary method of cultivation grew 2825 pounds of grain and 6175 pounds of straw; while by the electric method the same quantity of seed yielded 3625 pounds of grain and 9900 pounds of straw. Barley and wheat responded in a similar manner, while oats yielded even larger returns.

This method of applying electricity to vegetation is a tempting one to pursue on account of the abundance of atmospheric electricity at one's command.

In speculating on cosmical electricity, Prof. Elihu Thomson says: "The earth may possess the character of a huge conductor, the outer coating being the rarefied conducting air, the inner coating the ground and water surface, and the dielectric the dense air between." The electric potential on the top of the Eiffel Tower (984 feet high), he says, may be as great as 10,000 volts; and if the increase be 1000 volts for every 100 feet, on the average, it would rise to 1,000,000 volts at an altitude of twenty miles. So, we may liken the earth to a huge Leyden jar, the dense air acting like the non-conducting glass between the inner and outer metallic coatings of the jar. Sometimes in charging a Leyden jar the electricity will break through the glass (especially is it apt to do so if the glass contains lead), and ruin the jar thereafter for experimental purposes. Likewise, sometimes, electricity, under such high potentials, in the upper, rare atmosphere (in storm-clouds, for instance), will break through the intervening denser air and discharge itself into the ground or water—this we call a stroke of lightning.

Franklin raised his kite into such charged clouds, and their electricity came down the string and filled his Leyden jar, proving the identity of the electricity of the atmosphere with that of the plate machines ordinarily used to charge Leyden jars.

What if Paulin's geomagnetifers could be made to penetrate miles up into this reservoir of electricity and thus furnish an easy path for it to the earth ? It is interesting to speculate upon the possibility of our being able to tap this great storehouse of stimulus to vegetation—possibly even to human development—at will.

If we ask whence the outer, rare layers of our atmosphere get their electricity, we may come nearest a correct answer by saying from the sun, that great source of so many forms of energy. We know that displays of the aurora borealis, and also electric storms, which are so unwelcome to telegraphers, are most frequent during the prevalence of sun-spots, and we know that these spots are due to some great disturbance upon the sun. Whether the electricity thus generated upon the sun is carried to our upper atmosphere by minute particles thrown out by these eruptions, as is claimed by some, or whether we get it by induction across space, as is thought by others, we will not attempt to determine. We do know, however, that the electric potential does increase as we go up from the earth's surface. According to Mr. McAddie, it can be measured very accurately by means of his kite-experiment, which bears some resemblance to Franklin's historic one of so many years previous; there is, however, a very marked difference between the conditions which surrounded these two experimenters when they sailed their kites into the skies. Franklin courted the anger of the thunder-cloud and flew his kite, with its pointed wire, into the face of death—so far as he knew. His theory of the identity of electricity and lightning had not yet been proved—possibly it would be proved at the expense of its originator's life; he knew that the electricity of the Leyden jar was deadly to small animals, indeed his own life had been shocked into insensibility by it.

The ingenious Mr. McAddie flew his kite into the blue of a cloudless sky, and took note of the sparks discharged from the lower end of the insulated wire connected with it. By connecting an electrometer with the wire, he could usually tell whether the kite was rising or falling by reading the larger or smaller deflections of the needle.

It may be of profit to consider, even if very briefly, in closing this chapter, the effects of atmospheric electricity upon man—whether or not it assists in his physical development and well-being. Jean Paul Richter speaks of the value of the thunderstorm-bath, reminding us how "fresh, cheerful, and elastic" we feel after a "warm or tepid rain has penetrated to the skin," and how, after being exposed to a thunderstorm and becoming dry we are invigorated just as the flowers are when they stand erect and look refreshed after the passage of a storm. He says: "Why will they not receive this united fire and water baptism from above, and suffer themselves to be raised and healed by the wonder-working arm in the thunder-cloud?" He is practical when he advises a special suit of clothes for the purpose, and the forming of rain-parties when there is promise of wet weather in the warmer seasons. If we incline to Richter's belief, may we not reason that any form of dress which insulates us in a high degree from the earth, and thus prevents the passage of the atmospheric electricity through our bodies, is detrimental to us?

This may furnish one of the reasons why one feels best when he is able to run barefooted; also it may explain why in some parts of Germany it is claimed that many diseases may be cured by simply connecting one's self with an iron rod driven into the earth. Possibly we may refer any good which may be derived from the numerous patent devices for "electrolibrating," "polarizing," etc., to the fact that they are merely contrivances for electrically connecting one with the earth, and have nothing inherent in themselves as a means of electrically influencing the body. If there, perchance, be any good in these high-priced and much-advertised devices, the author would recommend as being just as efficacious (very possibly much more so, and certainly much cheaper), the connecting of one's ankles by means of an insulated wire with gas or water mains, which have such good connection with the earth.

If, indeed, atmospheric electricity benefits plants, as it certainly does, may it not be of use also to the collection of living cells which go to make man's body ? Possibly we think too lightly of this.

CHAPTER III

ELECTRICITY FROM BATTERIES APPLIED TO THE ROOTS OF PLANTS AND TO THE SURROUNDING SOIL

IN the previous chapters we dealt with frictional or static electricity, that developed by plate-electric machines or drawn from the upper atmosphere, and which possesses high electromotive force but is very deficient in quantity—a little stream, as it were, moving under great pressure. This, by reason of its great electromotive force, can penetrate the badly conducting air to plants and readily pass through them to the soil. Now we shall consider the uses of galvanic electricity, or that from batteries, and which, having low electromotive force, though capable of being delivered in large quantities, cannot be applied advantageously to the stalks of plants, but can be furnished readily to the soil surrounding their roots.

A simple form of experimentation, which first interested the writer and which yielded in the main such favorable results that he was led to continue his investigations, was as follows:

Two boxes of like size were filled with the same kind of soil, and in each was planted the same number of hemp seeds at the same depth. They were exposed to similar conditions of heat, light, and moisture. In the end of one of the boxes was inserted a thin piece of zinc, the height and breadth of the box, and in the other end a piece of copper of similar size. Both were pressed down almost to the bottom of the box, and were connected above ground by a copper wire soldered to their projections. Thus arranged the box was an earth-battery, the like of which has been used for running clocks and other machinery requiring but little current, and also by previous experimenters in electro-horticulture. The results were always in favor of the seeds planted in the earth-battery, the plants resulting from them being from twenty per cent. to forty per cent. in advance of those in the box without the zinc and copper.

Briefly, what goes on in the earth-battery is as follows: some compounds in the moist soil act chemically upon the zinc (positive element), one of the results of which is that a current of electricity is generated; this passes through the soil to the copper (negative element), up the copper to the wire above the soil and through it to the zinc, making a circuit. By inserting a sensitive galvanometer into this wire a current can be proved to be flowing by the deflection of the needle. It is this continuous current going through the soil which acts upon some of the compounds in it, and also upon the roots of the plants, giving us the good results we generally obtain. Ordinary galvanic cells, such as the "gravity," can be used to furnish the current; all that is needed is to attach the wire from the positive electrode of the battery to a metallic plate driven into the earth, and the wire from the negative to a similar plate at some distance from the other one. More current is furnished, but the expense is much greater.

The earth-battery in the hands of Spechnew, in the botanical gardens at Kew (London), achieved some surprising results. He sank plates of zinc and copper, about two feet square and connected by copper wires, into beds in which he planted various cereals and vegetables. He reported that in some experiments with cereals in these electrified beds the stalks were four times as large and the yield of grain one and one half times as great as in the beds not subjected to the electric treatment. He produced in this electrified soil a radish seventeen inches long and five inches in diameter, and a carrot nearly eleven inches in diameter and weighing five pounds. Both were juicy and fine-flavored. Fischer, of Waldstein, experimented largely with garden plants, placing his copper and zinc plates, each sixty-five by forty centimetres, in the soil thirty metres apart. In many plants he secured an increase of from twofold to fourfold. He claimed that the plants matured more quickly, and agreed with Spechnew that they were always free from disease, though often the surrounding plants were badly affected with fungoid growths.

Professor Warner, of the Agricultural College of Massachusetts, has verified at the Hatch Experiment Station many of the results of the European experimenters, and has given us some very interesting ones of his own. In experimenting with lettuce, he prepared two plots in a greenhouse so that they would be subject to like conditions and influences. In the one he buried, at a little depth in the soil, a system of copper wires consisting of series of from four to nine strands one half inch apart. He connected the wires with a battery of two cells, which sent a continuous current of electricity through them. These plots were in a part of the greenhouse which had been used for the raising of lettuce, and in which great trouble had been experienced from mildew. One of his objects was to see if the electric treatment would have any effect upon the mildew. Equal numbers of healthy lettuce plants, of the head variety, were set in the plots; those in the plot with the electric apparatus were planted over the wires so that their roots could come in contact with them. He reported that five plants out of fifteen in the electric plot were killed by the mildew, the other ten being "well developed and the heads large." In the corresponding unelectrified plot "only three plants had partially developed, and two of them were nearly destroyed by the mildew—only one was free from disease." It was noticed that when the current became weak, or was interrupted, the heads began to feel the destructive influence of the mildew; also that the largest heads were over the greatest number of wires and nearest where the wires were attached to the battery. A strange sight presented itself on examining the roots: it was found that they had "grown about the wires as if there they had found the greatest amount of nourishment." Professor Warner sums up by saying, "everything considered, the results were in favor of electricity. Those plants subjected to the greatest electrical influence were hardier, healthier, larger, and had a better color, and were much less affected by mildew than others." In later experiments he found that parsnips, salsify, radishes, and peas thrived especially well under the electric treatment, while turnips and beets responded to a less degree.

Spechnew, having obtained such excellent results from the use of earth-batteries, was led to perform the experiment of electrifying seeds before planting them, to see if the current would have any effect to make them develop sooner. He put some seeds into water until they swelled, and then transferred them to a glass cylinder, pressing copper discs against them at both ends. The disks were connected with the poles of an induction coil, and the faradic current applied to them for a minute or two. Immediately afterwards they were planted. Peas, beans, barley, and sunflowers developed in about half the time required for those not so treated, and the resulting plants were healthier looking, with larger leaves and brighter colors; the yield, however, was not increased.

The results reported by other experimenters correspond so closely with those detailed in this chapter that we need not give space to them.

The small expenditure connected with this line of experimentation in electro-horticulture should make it popular.

CHAPTER IV

EFFECTS OF THE ELECTRIC LIGHT UPON VEGETATION

IT is well known that if a plant be kept in a dark place it will lose its green color and pine away. Experimenting with plants deprived of sunlight, Professor C. W. Siemens found that if he substituted the light furnished by electricity, the plants would keep in a large measure their green color and grow almost as vigorously as with the sun shining upon them.

Recently a gardener, without any scientific ability, and without even the intention of experimenting, arrived at a similar conclusion. He was extremely puzzled one day to find that some lettuce plants at one end of his greenhouse were far in advance of those of the same age and variety at the other end. He was finally led to conclude that an arc-electric lamp, which had been burning every night at the prolific end of the lettuce bed, was the cause of his good fortune; and further experimentation proved his conclusion to be correct.

The arc-electric lamp furnishes a light very similar to sunlight, being, however, somewhat richer in the rays beyond the violet and slightly deficient in the orange rays. The use of an orange-colored globe makes it more nearly like sunlight, and favors its action upon vegetation. The naked arc-light, if too near some plants, exerts a detrimental action upon them, and one must carefully study the susceptibility of the individual plant in order to regulate the distance between it and the light. The length of time the lamp is kept burning and the color of the shade through which the light is permitted to pass are also matters of importance.

The value of interposing glass between the light and the plants has been demonstrated frequently: for instance, Dr. Bailey, of Cornell, whose work in electro-horticulture has been of the highest order, found that radishes under the naked light lost from forty-five per cent. to sixty-five per cent.; under a light covered by an opal globe the loss was but slight, while when the light was strained through the opal globe and the glass roof of the greenhouse there was an increase in both tubers and tops. He obtained similar results with beets and spinach. Cauliflowers were so influenced by the light as to grow tall and extend their leaves in a vertical direction, but they did not head so well as those grown without the light. Tulips and petunias grew taller and more slender, had richer hues, and bloomed earlier and more freely. Lettuce was from ten to twelve days earlier, and felt the influence of the light all over the greenhouse, which extended forty feet from the lamp. Another experimenter tells us that a 2000-candle-power arc-lamp will markedly influence a bed of lettuce sixty feet square.

Siemens found that the electric light was efficacious in producing chlorophyll in the leaves of plants; that it promoted the growth of the whole plant; and also hastened the development of flowers and fruit, giving to the former more intense coloring, and to the latter finer flavor. In strawberries the rich red color and fine flavor were especially noticeable, and the berries were brought to ripeness two weeks before the usual time. Melons, also, were quite responsive to the light, and were much improved in aroma.

In experimenting with the electric light one will find it very interesting to study its effects upon plants at different distances, as well as the effects of different transparent substances placed between it and the plants. Some plants are apparently scorched by the light, even if not near enough to feel the effects of its heat. The ultra-violet rays, which seem to cause this, are largely absorbed by plain glass. When a part of a plant is shielded from the light by a piece of ordinary glass one may sometimes see a distinct line of demarkation between the part so protected and that exposed to the glare of the light; even a single leaf may be partly scorched and partly of an intenser green as a result of its position in this respect.

But one must find the length of time each plant prefers the light to profit most by its influence, in addition to ascertaining its preference for intensity and for the color of the glass surrounding it.

Plants seem to have an individuality, and often show a decided liking for certain regulations in the use of the light in order to do their best when subjected to its influence.

One would think that plants need the darkness for their well-being, just as animals require the night for sleep and refreshment; but this has been declared by a prominent investigator not to be the case, or at least but to a very limited extent. Under the stimulus of the electric light they keep on growing at night almost as thriftily as in the daylight. What to us would be dissipation and end in disease, seems to them to be profitable pleasure, if the light is properly regulated. Mr. B. F. Thwaite tells us that the leaves of that beautiful plant, the *acacia cophanta*, which close at night, open almost magically when removed from the darkness into the brilliant beams of the arc-lamp; the leaves nearest the root being the first to be influenced.

We have been alluding to the effects of the steadily shining arc-light upon vegetation; but if it is flashed at short intervals upon plants it seems to have increased power, at least it will draw the plants more rapidly and strongly toward itself. They seem to be whipped up, as it were, by the violent alternations of intense light and darkness. Heliotropism is the name given to this effect; it deserves a fuller investigation.

It is not unlikely that in future experiments, devices will be used to graphically record the progress of the growth of plants. By using the method of M. Mach, one may see plants grow, and be able to follow them in some of their transformations.

His process consists, first, in photographing growing plants at suitable intervals, and, secondly, by means of a somewhat complicated apparatus, in passing rapidly before the eye the photographs of the plants in their various stages of growth. Thus, in a space counted by seconds, we may have passed before our wondering eyes the birth, developing, flowering, fruiting, and death of a plant. By reversing the order of the photographs we are amazed to see the fruit evanesce into the flower, the flower contract into the bud, the bud absorb into the stem, and finally the stem disappear into the ground.

By attaching a piece of fine platinum wire to a growing plant, and fastening a small piece of crayon to the other end of the wire, it is said that we may have recorded on a rotating drum, covered with white paper, tracings showing its growth. If we cover the drum with narrow strips of platinum foil, and connect them with one pole of a galvanic battery, and the wire attached to the plant with the other, and then place an electric bell in the circuit, we will hear, as the drum rotates, the ringing of the bell when the wire presses upon the foil, and have silence when the wire presses upon the spaces between the strips of foil. As plants are said to grow most rapidly between the hours of four and six in the morning, if we make the strips sufficiently narrow, or have a rapidly growing plant, we will have the bell rung quite frequently at our waking hour.

CHAPTER V

HOW DOES ELECTRICITY ACT UPON VEGETATION?

BEFORE speculating concerning the rationale of the action of electricity upon the growth of plants, it may be helpful to review, even very briefly, the manner in which plants get their nutrition from the air and soil.

The atmosphere is a mixture of one fifth oxygen and four fifths nitrogen, with varying percentages of carbon dioxid and vapor of water, besides minute quantities of a few other compounds. The leaves of plants have the power of breaking up the carbon dioxid (CO_2) and fixing its carbon, at the same time setting free its oxygen. This disintegrating action upon the carbon dioxid in woodlands is performed on such a large scale that sufficient oxygen is liberated to produce the exhilirating feeling one often experiences during an outing in the woods. This appropriation of carbon from carbon dioxid goes on when two conditions coexist : sunlight and the presence of chlorophyll in the leaves. To properly appreciate the value of sunlight to vegetation one must realize that it not only enables the chlorophyll to decompose carbon dioxid, but also that it is the stimulus which empowers vegetation to make chlorophyll, the constituent to which plants owe their various hues of green. It is well known that a period of rainy weather, with the absence of sunlight, diminishes very much the quantity of chlorophyll in plants; also that in dark cellars they lose it entirely, and, as a consequence, their lives, though an abundance of carbon dioxid be present.

From the soil plants get most of their water, and nearly all of their nitrogen (so very important to their well-being), besides the various salts of potash, lime, etc., which they require. Most of these substances exist in the soil in forms which can be absorbed readily by the roots; this is not the case, however, with nitrogen, so we offer a few words concerning it.

Nitrogen is an inert gas, colorless, odorless, and tasteless; it will neither burn nor support combustion, and yet it is indispensable to life—not only in plants but in human beings. Although it is so abundant in the air (simply mixed with oxygen), neither plants nor human beings are able to appropriate it directly from the atmosphere. It seems necessary that it first should be made into compounds before plants can utilize it. These compounds are generally formed by oxygen and hydrogen uniting with it under certain conditions: nitrous acid (HNO_2) and nitric acid (HNO_3) are examples. Usually compounds of nitrogen are produced by the decomposition of organic matter by ferments; thus prepared they are taken up readily by plants and made a part of them. However, the roots of some plants, under rare conditions, seem able to appropriate directly the nitrogen brought to them in the air which has been absorbed by rain-water. Legumenous plants are fortunate in this respect; an example will be given later.

Concerning the manner in which the electric light helps plants to grow, experimenters have given us some valuable information; but in relation to the action of the current itself upon vegetation much needs to be learned—and here is an inviting field for the microscopist as well as for the chemist.

The light furnished by electricity acts upon plants in a manner very similar to sunlight. It stimulates the formation of chlorophyll and assists in the decomposition of carbon dioxid, upon which plants feed so largely. That it helps in the formation of starch in the leaves can be proved in a very interesting manner. Keep a plant in darkness for several days so that the starch may disappear from its leaves. Then cover one of its leaves with a piece of tinfoil, and cut a letter or figure through the foil without injuring the leaf. Expose the leaf to the electric light, which will stimulate the production of starch in the part of the leaf which it reaches through the perforations in the tinfoil. After a couple of days pluck the leaf and at once put it into boiling water (to render the starch soluble), and then into alcohol (to dissolve out the chlorophyll). The leaf will now be colorless, but will contain dissolved starch in the parts which were exposed to the electric light. To render this visible, immerse the leaf in a weak solution of iodin, and the letter or figure will stand out in a blue color.

In considering the action of atmospheric electricity upon vegetation, we have to deal with a stimulus which exists in abundance. Plants grow most vigorously where it is most abundant, and with greatest rapidity in the early morning when the dew is more plentifully upon them, making them better conductors. Its most important action upon the stalks of plants is that of increasing their circulation of sap.

Discharges of electricity in the air, especially during thunder-storms, cause some union between the oxygen and nitrogen in the vicinity of the discharges, forming oxides of nitrogen, which, being soluble in water, are carried to the roots of plants and absorbed by them directly.

Electricity passed through the soil by earth-batteries, the geomagnetifer, or other means, has some action upon its chemical constituents. We are familiar with the effects of a current of electricity upon water (OH_2) when the electrodes of a battery are placed in it: from each molecule of water two atoms of hydrogen go to the negative electrode and one atom of oxygen to the positive. Since the time when Davy decomposed the alkalies, soda and potash, by means of electricity, nearly every compound has yielded to this mysterious power, which, as it were, shakes their molecules until the atoms composing them fly apart. In like manner currents of electricity may break up the more complex compounds in the soil into simpler ones, upon which the roots of plants can feed.

Spechnew found that one hundred pounds of earth, subjected to the electric current for a certain length of time, contained one ounce of soluble material, while a similar quantity of the same kind of earth not so treated contained but half an ounce.

Some observers believe that electricity decomposes the constituents of the soil much as quicklime does, and it is largely on this account that plants are more richly fed in electrified earth. Others think that, in some manner, under the electric influence, nitrogen from the air combines with some other substances in the soil, making compounds which are readily absorbed by roots of plants. A recent experimenter claims that the particles of electrified earth are set into molecular vibration, thus loosening the earth. Faraday, in his researches many years ago, declared that plants requiring much nitrogen for their development would be benefited by being grown in electrified earth.

Let us consider how uncombined nitrogen in the soil, carried there by the water, may be given to the roots of plants without first being formed into compounds. We will state the case of one of the legumenous plants, which plants find nitrogen so very necessary to their existence. It is well known that many of the legumes can sustain themselves in soils too poor in nitrogenous compounds to support other plants. They seem to do so by feeding directly upon the nitrogen brought to them from the air by rain-water, and this by the aid of certain bacteria at their roots. On the roots of the pea, for instance, we often find numerous tubercles; these used to be thought to be evidence of disease, and the microscope seemed to corroborate this by showing them to be filled with micro-organisms (bacterium radicicolus). However, it was soon ascertained that instead of causing harm to the pea plants these colonies of bacteria contributed very largely to their welfare. They actually fed the plants with nitrogen through their roots. If peas are planted in a soil which has been washed and calcined to deprive it of its nitrogenous compounds, they will soon become sickly and die; but if some water is made muddy with a little soil in which healthy peas are growing, and soaked to their roots, they become healthy and thereafter flourish. The water carries to their roots some of the bacteria from the ground in which the healthy peas are growing. These micro-organisms attach themselves to the roots, and while living, in a measure, upon the nutrition in them, more than pay for what they eat by giving to the plants through their roots quantities of nitrogen, taken in some mysterious manner from the air brought to the soil by the water. Let us wonder if electricity may not help in this matter by stimulating the activity of these bacteria, for it is said to favor very much the growth of peas when applied to the soil. Before directing our attention to the question of the action of electricity upon bacteria, let us notice the offices of some other bacteria in the soil.

Organic matter containing nitrogen, such as manure, is converted by fermentation into ammoniacal compounds. By one kind of micro-organisms in the soil these compounds are oxidized into nitrites, and by another kind the nitrites are raised to nitrates,[1] ready for absorption by the roots of plants. Both organisms are found in all good soils; in the future farmers may sow them in bad soils, not forgetting to sow with them some phosphates, sulphates, etc., as foods for the micro-organisms themselves.

Here, as very frequently elsewhere, man is dependent upon bacteria for some of the good things in life. In these days of antisepsis, when the tendency is to sterilize everything, especially our foods, it may soften our animosity towards the disease-producing micro-organisms to reflect that there are many of their kin which are friendly to us: the delicate flavors given to butter and to cheese are the results of their action; even the process of digestion is probaby dependent in a manner upon them.

But what has electricity to do with the action

[1] When we consider how scarce and costly nitrates are, we can rightly value the work of these two kinds of bacteria. They make the nitre beds of Chili and India by converting the organic matter deposited there by fish-feeding sea-birds into nitrates of soda and potash. The absence of rain in these localities causes the nitrates to effloresce upon the dry soil, from which they are easily collected; in other places they are washed away on account of their great solubility in water.

of bacteria in feeding atmospheric nitrogen to the roots of plants ? and what with their action in decomposing ammoniacal salts finally into soluble nitrates, ready for absorption by the plants ? Does electricity stimulate the functions of the bacteria ?

A current of electricity passed through water containing certain freely floating organisms causes them to take notice of the fact and accommodate themselves to it. Dr. Waller has shown that a vessel of water with parameciæ plentifully inhabiting it is curiously affected if a current of electricity is passed through it. The minute organisms at once form in line and rush towards the negative electrode, and if the current is reversed hasten the other way. One might think that the current drives the minute organisms with it, as it does some chemicals in cataphoresis; but, strange to say, other micro-organisms swim, as it were, against the current. D'Arsonville insists that electricity of high potential has a definite effect upon micro-organisms, and his remarkable experiment with the bacillus pyocyaneus, which caused it to change the color of its secretive pigment, is much in evidence. And then we know of the stimulating influence of thunderstorms upon fermentative germs; for instance, upon the lactic ferment, causing it to turn milk sour more quickly.

We think we have sufficient knowledge of the effects of electricity upon the cells of complex man to warrant us in believing that it does favor their nutrition; why not infer that it has a like action upon the cells [1] of plants, and, also, upon the functions of the bacteria concerned in feeding nitrogen to plants ?

In these early days of the X-rays of Roentgen, let us wonder what effect they may have, not only on plants above the soil, but especially on the roots and bacteria in the soil, which soil the rays can penetrate to a considerable depth.

So far experiments have not been conclusive. Professor Atkinson states that while plant-tissues absorb the Roentgen rays quite freely, there is no marked influence on the growing parts, and, also, that bacteria are negatively affected. Other experimenters report that exposure of the bacillus prodigiosus to the radiations of an X-ray focus-tube induces very marked increase of growth and peculiar changes in the pigment-forming powers of this particular micro-organism. Similar changes were noted in some of the lower forms of vegetable life, notably in the protococcus.

[1] Stanoievitch, a Russian scientist, has made the interesting observation that the markings produced by growth on a section of wood or vegetable, are very similar to those produced by sifting iron filings upon a plate of glass and holding the poles of a magnet directly under it. And he argues that there is an analogy between the actions of plants which arrange their cells in such definite positions, and the play of the magnet which makes the familiar "lines of force."

CHAPTER VI

SOME SUGGESTIONS AND A GLIMPSE OF AN ELECTRIC FARM OF THE FUTURE

THE simplest and cheapest method of getting electricity into the soil and to the roots of plants is by the use of some form of the geomagnetifer. In using this device we must be careful to arrange it so that the atmospheric electricity will come down the wire on the pole to the system of wires in the soil, and not down the pole itself to the earth immediately surrounding it. The pole may be made a non-conductor by being coated with resin, or it may be set into a non-conducting substance. As to the height of the pole, it should reach far above the surrounding trees or other high objects, or, better, the pole should be situated on elevated plots of ground. We must learn more about the relation of the area of soil beneficially affected to the height of the pole. We also must try to find out more about the nature of the soils most responsive to the application of electricity, as well as the varieties of plants most susceptible to its influence.

After the installation of a geomagnetifer, the main cost will come from the replacing of the distributing wires in the ground, which wires are subject to corrosion.

The use of earth-batteries seems to be a more reliable method of furnishing electricity to the soil. For their successful use the soil should be kept fairly moist, especially around the metallic plates. The use of weak acids in the vicinity of the zinc plates may be of advantage—if of any disadvantage, it would be that they consumed the zinc too rapidly, thus increasing the expense, possibly without a corresponding increase in the good done to the crop. The plates should be of ample size, and their distance apart should be regulated to suit the crops planted between them; the greater the distance the larger the resistance to the current and the less its strength. When a current of but little strength is wanted by soils or plants sensitive to it, rows of zinc plates should be connected with rows of copper plates at considerable distances from each other. If stronger currents are needed, the distance should be diminished. A sensitive galvanometer inserted in the wire above the ground will be of assistance in finding out the strength of current best suited to the circumstances of soil and crop; it will surely tell us whether or not a current is flowing through the soil: this will point out the cause of occasional failures in this form of experimentation. The action of the battery will slowly destroy the zinc, while the copper will last almost indefinitely; so it will be best to raise the zinc plates from the soil when no crop is being grown, or, at least, to disconnect the wires which join the zinc and copper plates. Iron can be used instead of the more expensive zinc, but the current furnished by the iron and copper battery is almost too weak to be of any service.

The advantages of this method over that in which the geomagnetifer is used are the absence of underground wires which corrode and have to be replaced in time, and the power to furnish a more constant supply of current. The one disadvantage is the interference the plates and wires offer to cultivation.

The earth-battery would seem to be the more useful in raising berries and vegetables in greenhouses or small plots, and the geomagnetifer in growing potatoes or cereals in fields.

When electricity can be generated cheaply enough by dynamos or other means, its application to soils in which crops are growing can be regulated to suit every condition; each soil and crop will get its dose as exactly and as effectively as the physician prescribes tonics and nutrients—possibly more so.

In using the arc-light the main things to be considered are the proximity of the plants to it, the nature and color of the shade interposed between it and the plants, the length of time the plants are exposed to its rays, and the hours of the day or night most suitable for its use.

If the arc-light is too near the plant, though not near enough to affect it by its heat, it may, nevertheless, *scorch* its leaves and cause serious damage. The ultra-violet rays are said to be responsible for this, as they, according to Professor Rowlee, "produce great activity in the protoplasmic contents of the cells, particularly of the palisade tissue, or hasten the physiological process. This activity calls at once for large supplies of water, and it is drawn first from the overlying epidermal cells; these cells being emptied of their contents, collapse like an empty grain bag. In other words, the vital activity is hastened so much by the naked light that the plant cannot supply materials quickly enough, and it is forced to death."

Plain glass will strain out these dangerous ultra-violet rays sufficiently to prevent this damage, or it may be avoided by removing the lamp to a sufficient distance from the plants.

Experiments are being conducted which may determine for us just what colors of lamp-shades are the most desirable for use in cultivating the various plants which are benefited by the arc-light. Experiments have been made with the spectrum of the sun to find out which of its rays are efficacious in causing the formation of woody fibre, which in the formation of starch, which in the formation of chlorophyll, etc., but the results have not been conclusive on account of the difficulty of maintaining the spectrum steadily at the same place, and on account of the short periods of time it could be depended upon for action. But with the arc-light the spectrum can be furnished continuously, and its different colors kept upon a number of similar plants as long as desired. Thus we may learn which colors are best suited to the varying needs of plants at the different stages of their growth. Here again we may meet the question of dosage, and may prescribe certain rays for early life, others for adult, or combinations for specially developing the starchy, saccharine, woody, or other substances in the plants; or we may hasten or retard the ripening of crops to suit the varying conditions of the market.

While it is stated by careful investigators that plants do not seem to need rest at night, yet further study of them under the influence of the electric light may put us in possession of facts which will enable us to give them their light-stimulus at the proper times and for the exact length of time, in addition to giving it of the right strength and color. The fact that diastase, which transforms starch into sugar, acts best in the absence of light, seems to argue that the leaves of plants, which make starch in the presence of light, should have periods of darkness to permit this transformation to go on satisfactorily; otherwise the leaves may become choked with starch, and the plant, although it has an abundance of starchy food, suffer because it cannot utilize it in the presence of continuous light. Some observers warn us not to give the light too freely at noonday, or when the heat is greatest, and others suggest that alternations in the dosage are of value; we have before made mention of the effects of heliotropism.

When one thinks of the combinations which can be made of the methods of furnishing electricity to the soil and to plants with the methods of furnishing electric light to the leaves of plants, he feels how little indeed has been accomplished, and sees ahead work for years of experimentation. And then there is the possibility that plants, in future generations, may become accustomed to being partly fed by the electric light, and partly by currents in the soil, and may adapt themselves to the new conditions to the increased profit of the horticulturist.

While the vast majority of the experimenters have reported results highly favorable to electro-horticulture, yet, as we have before pointed out, there have been a few who did not obtain the good results so enthusiastically heralded by others; it may be that in some localities of the earth's surface certain conditions obtain which render such places more favorable ones for such experimentation than others.

Experiments with earth-batteries may fail on account of the connecting wires above ground being twisted around the projecting plates instead of being soldered to them. In dealing with such feeble currents, no more resistance should be opposed to them than is absolutely necessary. And then the soil may be unsuitable for sufficient chemical action upon the zinc plate; possibly too scanty in proper mineral matter, or too. dry, and hence unable to generate a useful current. It is always well to test the strength of the battery, and still more important to see if there is any current flowing, by means of a sensitive galvanometer inserted in the wire connecting the plates.

The practical farmer will want to know if electric farming will increase his profits before he thinks seriously of adopting it. He may agree that it will be more scientific, perhaps more interesting, and likely less laborious, but will it pay? It is too early to give satisfactory figures concerning the results of the application of electricity to the growing of plants and vegetables, as experiments have not yet been made on a sufficiently large scale to furnish reliable statistics; but the smaller experimenters seem much encouraged, and some of them are now engaging in electro-horticulture much more extensively.

As regards the use of electricity as a motive power on the farm, the experiments have reached the stage where figures can be safely given in its favor. Recently Julius Muth, United States Consul in Mecklenburg, Germany, gives some interesting figures concerning a farm near that place run entirely by electricity. The dynamo furnishing the current is driven by a turbine whose power is furnished by a small brook, and the electricity is stored up in an accumulator of sixty-six large cells. The yearly expenses of running the farm under the old system were $1713.60, while under the electric system they were reduced to $1492.

Although it was not our intention to consider the application of electricity to the machinery of the farm in this little book, yet we give room to a statement of Otto Doederlein, United States Consul at Leipsic, in his report to the Department of State, in 1895, concerning "The Electric Plow in Germany." He says, after giving elaborate figures: "It is thus evident that the working expenses of the electric plow for extensive husbandry amount to less than half of those incurred in working the steam plow. This contrast is readily explained, for (1) the capital sunk in plant is only one third of that required for the steam plow; (2) the expenses connected with the generating of power are materially lower than is the case with the steam plow, in which a very considerable surplus power has to be raised in order to work the pulleys and brakes and to overcome the stiffness of the rope; (3) the expensive transport of water is herein entirely done away with." His reference is to the Electric Tilting Plow, made by Messrs. Zimmermann & Co. He also adds, "I have been informed by the director of the Haale factory that electricity will shortly also be used in digging out potatoes and sugar-beets."

When electricity can be furnished more cheaply than at present, what may not a combination of electric farm machinery, electric culture of the soil, and electric stimulation of plant-life mean to the farm?

The following extract from a lecture delivered by the writer some years ago at a Farmers' Encampment is appended, thinking a little electric speculation may interest some of the readers:

"The farmer we see in the future has no need of horses. Occasionally he may be found with a pair of spirited animals, with which to vary the monotony of riding in his speedy electric carriage. His work is done by electricity furnished by some near-by waterfall, or by a combination of wind-engine and storage-battery, or by some company which manufactures electricity cheaply and sells it to communities of farmers. His produce is sent to the nearest shipping station by means of electric railways on the highways, which run alike winter and summer, and which, when once put down, require no filling up of chuck-holes and no plowing up of the sides of the roadway and throwing of the dirt into the centre. Scattered over his farm are numerous poles carrying insulated wires. Let us go out to his wheat-field and see what he is doing. It is the time of harvest. We see an odd-looking reaper and binder; from it, as it moves rapidly along, there pays out some insulated wire which connects the reaper with the wire coming to the field from the highway, through which wire it receives the energy which runs it. Thus the farmer with great rapidity cuts, binds, and shocks his wheat; he does the work alone and complains not of weariness, but only of a sense of loneliness. As he stops his machine for a few moments to shift the wire, he tells us that this method is getting too slow for him, on account of the reeling and unreeling of the wire, and that he is thinking of buying the latest patent which carries its own electric supply in storage-batteries, only he fears that the recent experiments looking toward making electricity directly from coal are so near to success that this new machine, in turn, will soon become old-fashioned.

"After he is done a wagon comes out, moved by the same mysterious force, and gathering the sheaves, takes them to the barn. In course of time an electric thresher, which cannot set the barn on fire from red-hot cinders, separates and cleans the wheat; and soon the electric railway transports it to the market.

"His electric plow is quite an improvement on the one which not long ago turned up the first furrow in American soil at the Kansas sorghum experiment station, and his electric harrow pulverizes the ground to an evenness that is marvellous. . . .

Among the many lesser inventions of which he makes use, we notice a simple device to protect some favorite trees from the invasion of caterpillars. The trunks of the trees have two narrow bands of copper around them at short distances apart. These bands are connected by wires with the poles of a battery capable of delivering a very strong current. When a caterpillar crawls up one of these trees and crosses the metallic bands, it is in the same unpleasant situation as the murderer in the 'eloctrocution chair' at Sing Sing. Its body makes the connection between the terminals of the battery, and it goes no farther. If the current is powerful enough a diminutive arc-light is the result, and a cinder all that is left of the caterpillar. Indeed he is tempted to use this method, with some modifications, in dealing with the chicken thief, the burglar, and even the ubiquitous tramp.

"See the huge earth-batteries and tall geomagnetifers he uses in forcing his crops; how he spreads electricity, as it were, through the soil, and keeps large arc-lamps burning at night to still further assist in hastening the growth of his farm products. With the heat generated by these lamps, or by means of special resistance coils, generating it more abundantly, he is able to prevent frosts doing damage to his earlier and more tender fruits and vegetables.

"Had the late rain-producing experiments been successful, we might even picture this fortunate farmer calling down the refreshing showers whenever he thought his crops needed them. And if he believed, with Jean Paul Richter, that the thunderstorm-bath was as refreshing and invigorating to the human system as to the trees and flowers, he would invoke the storm with his bombs when he thought his grain needed rain, regardless of the fact that there was a picnic in the wood or a farmers' encampment in the grove—indeed, he would take out his wife and children and form a 'rain-party,' and be invigorated and strengthened by the 'wonder-working arm of the thunder-cloud.'

"Our electric farmer, besides using electricity to assist in maturing his crops, has learned how to apply it to the destruction of one of his greatest enemies—weeds. With a dynamo furnishing a current stepping up from 2000 to 24,000 volts, as needed, he sends the current through the weeds by means of brushes of fine wire passing among their tops as his generator moves over the field,—the other pole of the circuit being connected with the ground through the wheels of the machine carrying the dynamo. This strong current breaks up the cellular tissues of the weeds and thus destroys them—just as, on a larger scale, a stroke of lightning destroys a tree. . . . In picturing the electric farm one has a very large range of probabilities to draw upon, but there is ever the danger of his letting his fancy run riot and of making the electric farm of the future appear a very Utopia; there will ever be plenty of hard work for the farmer, even on the model electric farm, but he will have more pleasure and satisfaction in his work, and, it is to be hoped, more profit from it."